E-6A
HARDNESS ASSURANCE, MAINTENANCE & SURVEILLANCE PROGRAM

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ABSTRACT

The challenge facing aircraft program managers and the Fleet is to ensure that the electromagnetic hardness of design is maintained throughout the aircraft life-cycle. The electromagnetic pulse (EMP) community must work closely with aircraft program managers and aircraft design contractors to properly integrate the logistics elements necessary to accomplish this effort. This process must begin early in the acquisition phase and be dynamic enough to evolve as changes in life-cycle mission requirements occur.

This paper identifies the Hardness Assurance, Maintenance, and Surveillance Program for the U. S. Navy's E-6A aircraft. The program includes various test techniques that are used to monitor aircraft hardness integrity and maintenance procedures to direct the hardness critical process. A database was also developed which integrates all test and maintenance data to aid aircraft hardness surveillance.

The E-6A Hardness Assurance, Maintenance, and Surveillance Program was developed to meet the needs of the TACAMO Fleet and serves as a model for the U. S. Department of Defense.

INTRODUCTION

The E-6A design specification required that aircraft EMP hardening features provide a substantial margin of protection above upset for all flight critical and mission essential equipment. A layered hardening approach was selected to accomplish this requirement. Hull hardening is the primary hardening feature of the E-6A. This feature includes the use of conductive door seals and embedded etched screen windows to make the hull like a solid metal enclosure. Arrestors, filters, dielectric isolation devices, and conductive pulleys protect from aperture penetrations such as antennas and control cables. Shielded interior wiring, as well as, RF tight consoles and cabinets were integrated to increase shielding effectiveness.

Hardness assurance tests were conducted on each aircraft to verify specification compliance. Hardness maintenance procedures were also developed to ensure that Fleet operations, logistic support, and/or maintenance do not degrade the designed hardness. Finally, hardness surveillance tests and inspections are performed periodically to monitor aircraft hardness integrity.

TO WHOM IT MAY CONCERN:

Here is a copy of Professional Papers written by various people here at the Naval Air Warfare Center Aircraft Division. It was requested that a copy of each of the professional papers be sent to DTIC for retention.

If you have any questions, please contact Dorothy Reppel, 326-1709 or (301) 826-1709.

P.S. All the enclosed papers have been cleared for public release.

HARDNESS ASSURANCE

Hardness assurance is a result of procedures and processes applied during the development of a system to verify and preserve the system's nuclear hardness. Hardness assurance includes controls to prevent hardness degradations, procedures for detecting possible hardness degradations, and test and analysis to confirm specification compliance. Based on this approach, an EMP qualification test was conducted on the first production E-6A aircraft at the Naval Air Warfare Center, Patuxent River, Maryland from 6 September through 6 December 1988.

The EMP Qualification Test included approximately 1000 measurements on 420 test points and was conducted in three phases as follows:

a. The Active Systems Test (AST), Phase I, required all aircraft engines running at ground idle with all electrical systems powered. The fuselage was oriented parallel to the Horizontal Polarized Dipole (HPD) simulator antenna and fuel tanks were inerted with nitrogen gas. A qualified flight crew and experienced operators visually monitored all flight critical equipment (FCE) and mission essential equipment (MEE) for upsets and recorded all observations. The AST was deemed successful if no EMP induced upsets of operated FCE or MEE occurred.

b. The Passive Systems Test (PST), Phase II, required all aircraft systems configured to simulate an in-flight mode. Selected FCE and MEE cables were instrumented with probes to measure transient current responses and "break-out-boxes" were installed to measure current on the center conductors of shielded cables. Access panels were installed to allow fiber optic links to exit the aircraft without impacting the aircraft's electrical configuration. The PST was conducted using the HPD Simulator, as well as, the Vertical Polarized Dipole (VPD) Simulator. Aircraft orientations during the PST included fuselage parallel/perpendicular to the HPD antenna and fuselage nose/tail adjacent to the VPD antenna respectively. The PST response measurement test was deemed successful when all response measurements were obtained and scaled appropriately for the difference between simulator drive levels/frequency content and projected threat conditions.

c. The Direct-Drive Test (DDT), Phase III, required operating FCE and MEE systems, one at a time, while coupling threat level currents onto individual equipment cables and connectors. Phase II response data were used to establish the direct-drive levels and scaled-to-threat waveforms. Individual cables and connectors were driven to the required margin above the scaled-to-threat level. The DDT was deemed successful when test points were verified to have an upset safety margin equal to or greater than the specification requirement.

The E-6A EMP Qualification Test established a baseline for subsequent Production Acceptance Tests (PATs) that were conducted on each aircraft prior to delivery to the Fleet.

The approach for conducting each PAT was identical to the Qualification Test, however, the amount of test points was significantly less. Test points from the Qualification Test that had very low response measurements were eliminated from the PATs to streamline this process. Data gathered during each E-6A EMP PAT established each aircraft's baseline for life-cycle Hardness Surveillance Tests and major aircraft modifications.

ARDNESS MAINTENANCE

Hardness maintenance procedures are applied during the service life of a system to ensure that the designed hardness does not degrade. Therefore, a comprehensive hardness maintenance program was developed for the E-6A which begins with training.

All personnel associated with operations, logistic support, and/or maintenance of the E-6A aircraft receive training appropriate to their skills. Appropriate training for operations personnel may include an awareness of EMP, the effect it has on systems, and the Hardness Critical Process (HCP). However, logistic support personnel must be cognizant of Hardness Critical Items (HCIs) and the improper substitution of non-HCIs and maintenance personnel must receive specialized technical training.

The hardness maintenance approach for the aircraft was to integrate the performance of HCPs with normal maintenance actions to prevent degradation of system hardness and/or restore hardness degradation as it occurs. Typical HCPs include the inspection and cleaning of faying surfaces, as well as performing bonding checks after removal and replacement of HCIs.

Aircraft technical publications play a key role in the quality of maintenance actions. All E-6A technical publications were developed to include the identification of HCPs and HCIs. There are no assumptions to be made about the applicability of a HCP when a technician refers to a maintenance manual to perform a task. When ordering replacement parts, the technician, as well as logistic support personnel can easily identify which items are HCIs so that inappropriate substitutions are not made.

Failure of HCIs such as door gaskets and windshields may be detected by visual inspection, however, test equipment may be required to troubleshoot other components. Milliohm and capacitance meters can be used to verify bonding and check simple filters. However, many HCIs require the use of more complex test equipment such as the Hardness Maintenance/Surveillance (HM/S) Tester developed by ALCATEL and the Test Bench For Nuclear Hardness (TBNH-6F) system developed by Rockwell-Collins France which will be discussed further.

The goal for performing hardness maintenance on the E-6A aircraft is to ensure that the hardness integrity of the aircraft is preserved during maintenance and logistic support activities. Adherence to sound maintenance practices and implementation of stringent configuration control and repair procedures are key elements in the success of this effort.

HARDNESS SURVEILLANCE

Hardness surveillance of the E-6A is comprised of periodic tests and inspections performed by the Fleet Technical Support Team to monitor life-cycle system hardness integrity. Hardness surveillance compliments hardness maintenance since both tasks are required to ensure that the aircraft hardness is intact. Whereas hardness maintenance employs qualitative measures to ensure hardness integrity, Hardness surveillance yields quantitative information relative to the status of hardness integrity.

An EMP Survivability Control Plan was developed to provide guidance to the Fleet Technical Support Team and for managing hardness surveillance efforts. It defines the tasks required to adequately monitor the hardness of the E-6A and will dynamically evolve as aircraft modifications occur or mission requirements dictate. As described in this document, hardness surveillance of the E-6A includes Hardness Protection Device Inspections(HPDIs), field surveillance assessments, and system level Hardness Surveillance Tests.

HPDIs are performed during scheduled maintenance. These qualitative/quantitative tasks include visual inspection and/or cleaning of mechanical HCIs, as well as test and inspection of linear and non-linear HCI's. As discussed earlier, test equipment such as the TBNH-6F has been developed to aid in this process.

The TBNH-6F was designed to test both linear and non-linear HCIs by evaluating component characteristics such as attenuation, capacitance, inductance, resistance, firing voltage, and leakage current. The TBNH-6F computer controlled integrated system includes a network analyzer, impedance analyzer, picoampere meter, and switching/interface components. This system is transportable and can be used to test HCIs without removing them from the aircraft.

Field surveillance assessments are conducted by the Fleet Technical Support Team using the low-level, continuous wave HM/S Tester which consists of a transmitter, receiver, and various probes and antennas. This system can be operated in two modes; global and local. The global mode illuminates the entire aircraft to evaluate any changes in overall shielding effectiveness relative to baseline data. The local mode is used to aid fault isolation of suspected degraded components.

System level Hardness Surveillance Tests will be conducted periodically throughout each aircraft's life-cycle both randomly and when HPDI or field assessment data indicate potential survivability/vulnerability concerns. New baselines must also be established following major aircraft modifications.

All hardness assurance, maintenance, and surveillance data are integrated into a relational database. This database contains an invaluable source of qualitative and quantitative information regarding aircraft configuration, hardness integrity, and HCI reliability/maintainability.

SUMMARY

The E-6A Hardness Assurance, Maintenance, & Surveillance Program is dynamic. It has integrated all the necessary elements to ensure life-cycle EMP hardness integrity. The success of this program is directly attributed to well thought out advanced planning and timely implementation.

E-6A
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E-6A
HARDNESS ASSURANCE, MAINTENANCE & SURVEILLANCE PROGRAM

- HARDNESS ASSURANCE
  - QUALIFICATION AND PRODUCTION ACCEPTANCE TESTS TO ENSURE COMPLIANCE WITH DESIGN SPECIFICATIONS
- HARDNESS MAINTENANCE
  - COMPREHENSIVE PROCEDURES TO ENSURE THAT FLEET OPERATIONS, LOGISTIC SUPPORT, AND/OR MAINTENANCE DO NOT DEGRADE THE DESIGNED HARDNESS
- HARDNESS SURVEILLANCE
  - SYSTEM LEVEL AND FIELD SURVEILLANCE TESTS & INSPECTIONS PERFORMED THOUGHOUT THE AIRCRAFT LIFE-CYCLE TO MONITOR HARDNESS INTEGRITY

E-6A HARDNESS ASSURANCE

- QUALIFICATION AND PRODUCTION ACCEPTANCE TESTS

  - ACTIVE SYSTEMS TEST (QUALITATIVE)
    - ALL AIRCRAFT SYSTEMS OPERATED AND MONITORED FOR UPSETS DURING PULSE EVENTS

  - PASSIVE SYSTEMS TEST (QUANTITATIVE)
    - RESPONSE MEASURMENTS MADE ON ALL FLIGHT CRITICAL AND MISSION ESSENTIAL SYSTEMS
    - DATA CORRECTED FOR INSTRUMENTATION EFFECTS AND EXTRAPOLATED TO DOUBLE EXPONENTIAL WAVEFORM

  - DIRECT-DRIVE CURRENT INJECTION TEST
    - WORST CASE COMPOSITE EXTRAPOLATED WAVEFORMS WERE REPRODUCED, AMPLIFIED, AND COUPLED TO TEST POINTS TO ESTABLISH SAFETY MARGINS

- NEW BASELINES ARE ESTABLISHED AFTER MAJOR MODIFICATIONS

E-6A HARDNESS MAINTENANCE

- PROCEDURES HAVE BEEN DEVELOPED TO CONTROL, DETECT AND CORRECT HARDNESS DEGRADATIONS AND FAILURES
  - MAINTENANCE PERSONNEL ARE TRAINED IN THE HARDNESS CRITICAL PROCESS
  - HARDNESS FEATURES ARE IDENTIFIED AS HARDNESS CRITICAL ITEMS IN ALL MAINTENANCE PUBLICATIONS
  - HARDNESS PROTECTION DEVICE INSPECTIONS ARE INTEGRATED INTO SCHEDULED MAINTENANCE PROGRAM
- SOUND MAINTENANCE PRACTICES ARE KEY TO ENSURING HARDNESS INTEGRITY
- MAINTENANCE MANAGEMENT TEAM MEETINGS PROVIDE FORUM TO ADDRESS MAINTENANCE ISSUES

E-6A HARDNESS SURVEILLANCE

- FLEET TECHNICAL SUPPORT TEAM PROVIDES ON-SITE TECHNICAL AND ENGINEERING ASSISTANCE TO THE FLEET
  - CONDUCT PERIODIC ASSESSMENTS TO MONITOR HARDNESS INTEGRITY OF FLEET AIRCRAFT
  - REVIEW, ANALYZE, AND ARCHIVE EMP MAINTENANCE DATA
  - ASSIST IN TROUBLESHOOTING AND INVESTIGATING EMP PROTECTION DEVICE ANAMOLIES AS WELL AS OTHER ELECTROMAGNETIC ENVIRONMENTAL EFFECTS ISSUES
- SYSTEM LEVEL SURVEILLANCE TESTS CONDUCTED RELATIVE TO SCHEDULED MAINTENANCE EFFORTS
- HAMS DATABASE ASSISTS IN CHARACTERIZING THE HARDNESS INTEGRITY OF EACH AIRCRAFT

E-6A
HARDNESS MAINTENANCE & SURVEILLANCE TEST EQUIPMENT

- HARDNESS MAINTENANCE SURVEILLANCE TESTER
  - LOW-LEVEL CW TECHNIQUE
  - HULL HARDENING SHIELDING EFFECTIVENESS TEST
    - GLOBAL ILLUMINATION
  - FAULT ISOLATION
    - LOCAL ILLUMINATION
- TEST BENCH FOR NUCLEAR HARDNESS (TBNH-6F)
  - PERFORMS DETAILED HCI COMPONENT PARAMETER ANALYSIS
  - CHARACTERIZES BOTH LINEAR AND NON-LINEAR COMPONENTS

E-6A
HARDNESS ASSURANCE, MAINTENANCE & SURVEILLANCE DATABASE

- RELATIONAL DATABASE SOFTWARE
- INTEGRATED DATA
  - ▸ SYSTEM LEVEL TESTS
    - QUALIFICATION, PRODUCTION ACCEPTANCE, SURVEILLANCE
  - ▸ FIELD ASSESSMENTS
  - ▸ EMP HCI MAINTENANCE
  - ▸ CONFIGURATION CHANGES
  - ▸ SCHEDULED MAINTENANCE ACTIONS
- ALL DATA IS CROSS REFERENCED BY WORK UNIT CODES

E-6A
HARDNESS ASSURANCE, MAINTENANCE & SURVEILLANCE DOCUMENTATION

- SYSTEM LEVEL TEST PLANS, PROCEDURES AND REPORTS
- NUCLEAR HARDNESS MAINTENANCE AND HARDNESS SURVEILLANCE PLAN
- ELECTROMAGNETIC PULSE SURVIVABILITY CONTROL PLAN
- FIELD ASSESSMENT PROCEDURES
- SCHEDULED MAINTENANCE, INSPECTION, AND TEST SPECIFICATIONS

SUMMARY

- EMP SURVIVABILITY OF THE E-6A AIRCRAFT IS ENSURED BY:
  - A COMPREHENSIVE MAINTENANCE PROGRAM TO PRESERVE THE HARDNESS INTEGRITY OF DESIGN
  - STRINGENT CONFIGURATION CONTROL
  - SURVEILLANCE TESTS AND INSPECTIONS TO MONITOR DEGRADATION THROUGHOUT THE AIRCRAFT LIFE-CYCLE